Nonlinear Time Series Analysis

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***Abstract*-** We start by opposing the two paradigms of stochasticity (most clearly represented by Gaussian autoregressive models) and deterministic chaos. We present several examples (heart, nephrons, epileptic seizures) where evidence for the latter has been found. We then start the more technical part by discussing time delay embeddings and the choices of parameters for them. After that we shall discuss noise reduction algorithms and algorithms for signal separation based on the geometry of embeddings. In particular we shall present the extraction of fetal heart beat from a univariate ECG signal. We then discuss classical invariants (metric entropy, attractor dimension, Lyapunov exponents) and argue why using them as indicators for chaotic determinism is not very useful. The same should be true also for alternatives like false nearest neighbors or forecasting errors. In contrast we shall argue that strict determinism is not needed for the arsenal of nonlinear time series analysis to be useful.

We shall argue that the above observables can indeed be very useful in clinical applications. As an illustration we shall discuss evidence that epileptic seizures can be predicted and epileptic foci can be localized by using dimension-like observables. Typical features of deterministic chaos are the existence of unstable periodic orbits and the possibility to control such systems by arbitrarily small perturbances. We shall comment on claims that such periodic orbits have been found in biomedical systems, and we shall discuss whether chaos control could eventually be used in intelligent heart pacemakers.

Finally, we shall discuss various methods to study interdependencies between different time series. These include cross correlation and coherence, mutual information, phase synchronization, and other interdependence measures. We shall discuss their usefulness in EEG analysis, in particular for epilepsy patients. Among these measures, of particular interest are asymmetric measures because they could, independent of time delays, indicate causal connections. Again this is illustrated with epileptic EEGs.

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Abstract

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